

**BELLCOMM, INC.**

1100 Seventeenth Street, N.W. Washington, D. C. 20036

**SUBJECT:** Discussion of the STAC Question  
Regarding Implications of a  
Plane Change Restriction at LM  
Ascent - Case 310

**DATE:** November 28, 1967

**FROM:** D. R. Anselmo

ABSTRACT

The advantages and disadvantages of using a lunar parking orbit orientation that would eliminate a plane change by the CSM at LM ascent are pointed out. The principal disadvantages are an increase of up to 4500 pounds of SPS required propellant and the possible conflict of the required lunar orbit orientation and site approach path restrictions due to terrain roughness. The advantages pointed out are the deletion of one required SPS burn and the possibility of reducing MSFN tracking requirements for maintaining knowledge of the CSM lunar orbit. It is concluded that the magnitude of the propellant cost and attendant loss of mission opportunities outweigh any advantages accruing from the deletion of the plane change requirement.

(NASA-CR-93092) DISCUSSION OF THE STAC  
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MEMORANDUM FOR FILE

Introduction

The present Apollo trajectory planning provides for an in-plane LM descent to the landing site and in some cases imposes an approach path restriction; otherwise the orientation of the lunar parking orbit relative to the landing site is a free variable. In general mission planning will result in some required plane change by the CSM prior to ascent if the ascent maneuver is to be in-plane. While a lunar orbit could be calculated which would eliminate such a plane change, such planning incurs positive disadvantages which are enumerated in this note.

Lunar Parking Orbits

The motion of the lunar orbit plane relative to the lunar surface is governed primarily by two effects. The primary effect is the rate of the moon's rotation about its own axis and the second is the precession of the orbit due to the oblateness of the moon. For retrograde lunar orbits, which are required for free return trajectories, the effects are subtractive. For lunar orbit inclinations up to 20 degrees the effective (rotation and precession) eastward drift of a lunar landing site relative to the CSM orbit is approximately 12.1 degrees per day.

The Apollo Mission Profile has been designed to use an in-plane lunar descent. Hence the CSM/LM orbit plane at the time of descent must contain the desired lunar landing site. In order to determine the CSM parking orbit plane which will result in no plane change requirement at LM ascent one need consider landing site latitude, stay time, and lunar orbit inclination. Figure 1 shows a lunar orbit ground track and the effective drift of the landing site projected onto a latitude/longitude grid. Point A represents the desired landing site location relative to the CSM/LM orbit trace at lunar orbit insertion. Since the landing site moves to the east relative to the orbit at approximately 1/2-degree per hour, at LM descent the landing site has progressed to B

and an in-plane descent can be performed. The distance  $\overline{BD}$  determines the surface stay time which will result in an in-plane ascent for the orbit trace designated I. Orbit II would result in a different stay time for an in-plane ascent, the distance here indicated by  $\overline{BD'}$ . Thus it is seen that for any required stay time at a specified lunar landing site it is possible to select a lunar orbit plane which would result in no plane change required at LM descent or ascent. This plane is uniquely determined by the points B and D.

It should be noted that the maximum plane change required during the stay time is not zero. If any time lunar lift off capability is desired, the CSM fuel must be budgeted for the maximum required plane change shown in Figure 1 as  $\theta_{\max}$ .

#### The Free Return Mission

The CSM/LM must be placed into the specified lunar parking orbit with a major SPS engine firing and at the end of the lunar stay the CSM must be boosted onto the transearth trajectory with another major SPS firing. It is not surprising that the propellant required for these maneuvers is dependent upon the orientation of the lunar parking orbit plane and hence the lunar orbit orientation is treated as a trajectory optimization parameter.

To determine the cost of eliminating the lunar orbit plane change in the nominal mission, trajectories to Apollo sites were generated for 1969. The results are given in Figure 2 for a central and west site for the year 1969, and in Figure 3 for all Candidate Apollo sites in the month of June 1969. Table I lists the sites and their selenographic locations. These figures represent the increase in spacecraft injected weight due to increased propellant requirements which result when the lunar parking orbit orientation is constrained by requiring that no plane change be made on LM descent or nominal ascent. It can be seen that in some cases the total SPS propellant requirements increase by as much as 4500 pounds. In other cases the optimized mission parking orbit orientation coincided with the zero plane change parking orbit and no penalty was observed.

TABLE I

Site	Latitude	Longitude
II P2	2° 40'N	34° 0'E
II P6	0° 45'N	23° 37'E
II P8	0° 25'N	1° 20'W
II P11	0° 25'N	19° 55'W
III P9	3° 05'S	23° 15'W
III P11	3° 30'S	37° 10'W
II P13	1° 40'N	41° 40'W
III P12	2° 20'S	43° 55'W

#### Approach Path Limits

As the reduction and study of Lunar Orbiter photography progresses it is expected that for some candidate Apollo landing sites an approach azimuth restriction will be imposed. These restrictions will be the result of terrain roughness in the approach path at certain azimuths which is unacceptable due to the corruption of landing radar data being supplied to the LM guidance system. It is possible that for some lunar landing sites the orbit determined by a no-plane-change constraint would result in an approach azimuth within the unacceptable region. Hence in some cases the zero plane change strategy would eliminate an otherwise useful landing site.

#### Possible Advantages

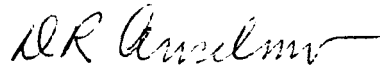
The deletion of a plane change maneuver by the CSM in lunar orbit would relieve the MSFN tracking requirements to some extent. The need for re-establishing knowledge of the CSM orbit after an SPS maneuver would be eliminated. This same advantage could be realized by requiring that the LM make a plane change during ascent and rendezvous; however, for operational and performance reasons, a LM plane change maneuver is not planned (a 1/2-degree capability is provided for a touch up maneuver by the LM).

The elimination of one SPS burn from the mission profile could have reliability implications; however, no problems with multiple SPS restarts have been identified at this time.

#### Conclusions

The additional constraint requiring, in the nominal case, no lunar orbit plane change at LM ascent does not appear advantageous at this time. The primary disadvantage is the additional SPS propellant requirement of up to 4500 lbs. The possible loss of mission opportunities due to approach path restrictions is also serious.

Operations planning and software development could not take advantage of the possible simplifications since there is a requirement for any orbit LM launch, which would require a plane change in a contingency case.



2013-DRA-srb

D. R. Anselmo

Attachment:

Figures 1, 2, 3

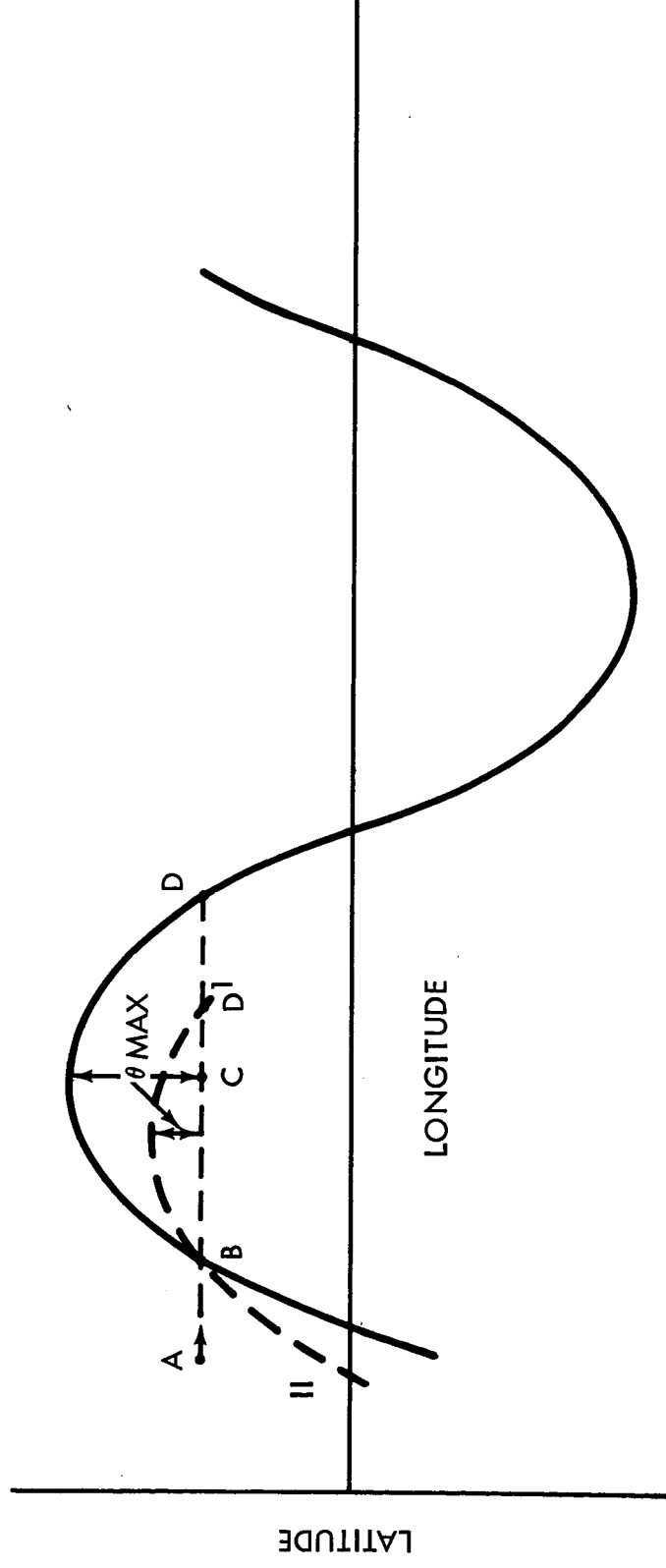


FIGURE 1 - LUNAR ORBIT GEOMETRY

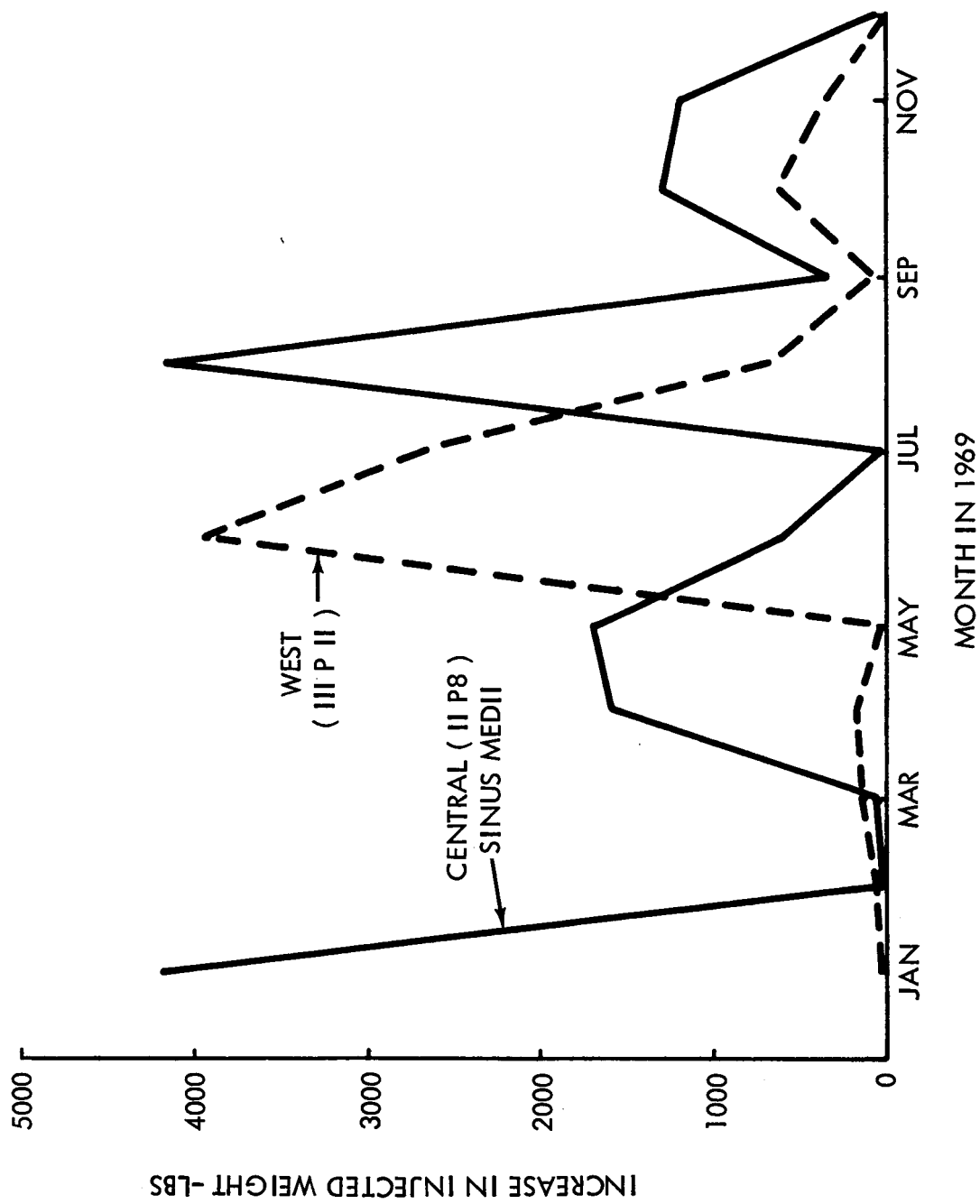
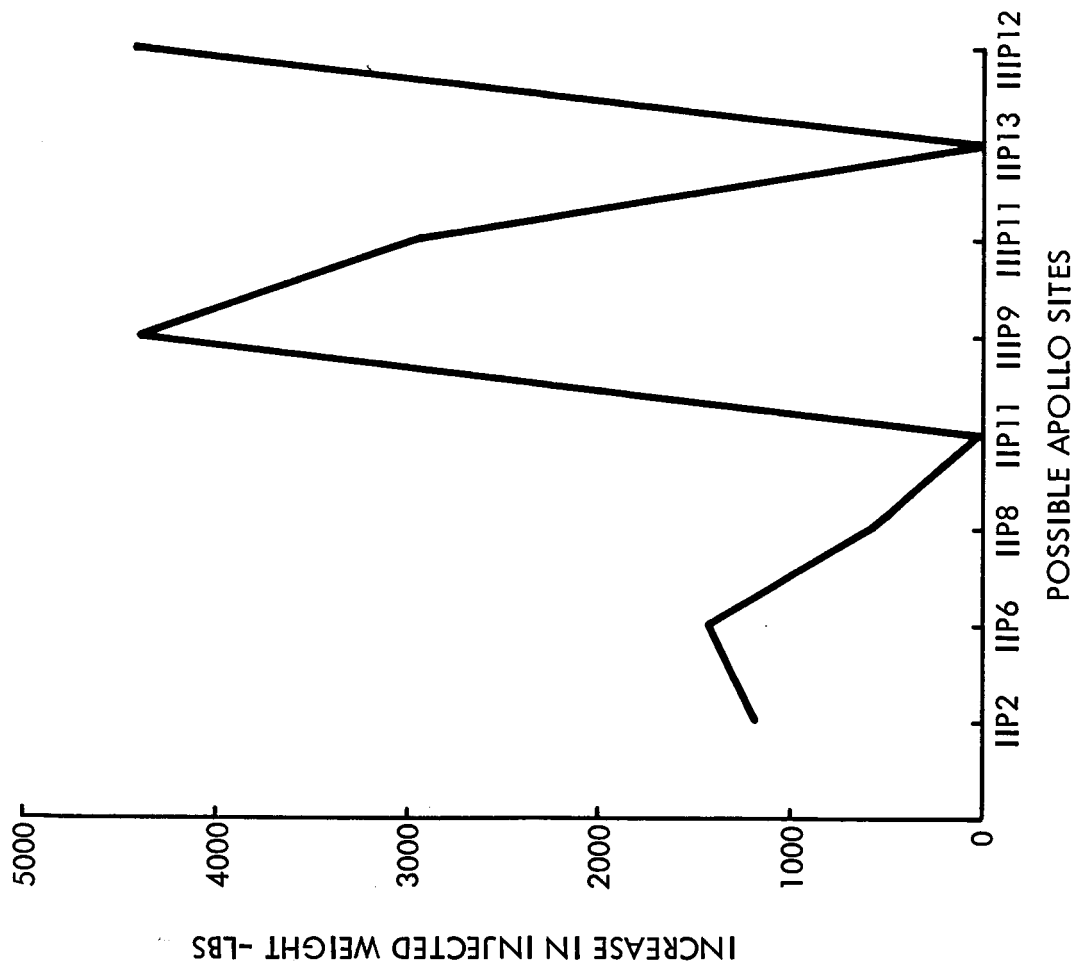


FIGURE 2 - INJECTED WEIGHT PENALTY FOR CONSTRAINING LUNAR ORBIT INCLINATION



JUNE 1969 (PACIFIC INJECTION )

FIGURE 3 - INJECTED WEIGHT PENALTY FOR CONSTRAINING LUNAR ORBIT INCLINATION

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